CLAIMS

I claim:

1. In a method of calculating at least one physical parameter of a film in which the improvement comprising, the at least one physical parameter is related to scattering caused by interband states.

2. The method according to claim 1, wherein the at least one physical parameter is an optical property of the film.

3. The method according to claim 1, wherein the at least one physical parameter is selected from the group consisting of the optical dispersion, refractive index and the extinction coefficient of the film.

4. The method according to claim 1, wherein both the refractive index and the extinction coefficient of the film are calculated.

5. The method according to claim 1, wherein the at least one physical parameter is related to the scattering caused by interband states using a model.

6.   The method according to claim 5, wherein the model

includes a quantum mechanical transition equation for transitions

between at least one of valence and conduction bands and interband states

in a band gap.

7.   The method according to claim 6, wherein the equation is:

$$\varepsilon_2(\omega) = \begin{cases} A\dfrac{\sqrt{E-E_D}}{E^2}, & \text{for } E > E_D \\[2mm] 0, & \text{for } E < E_D \end{cases}$$

where $\varepsilon_2(\omega)$ is the imaginary part of the dielectric function;

E is the incident photon energy;

E_D is the energy level of the interband state; and

wherein the values for A and E_D are fitted parameters obtained

from measured data of an optical property of the film.

8.   The method according to claim 7, wherein the model further

includes the equation:

$$\varepsilon_1(\omega) = \begin{cases} \varepsilon_1(\infty) + A\dfrac{2\sqrt{E_D} - \sqrt{E_D+E} - \sqrt{E_D-E}}{E^2}, & \text{for } E < E_D \\[2mm] \varepsilon_1(\infty) + A\dfrac{2\sqrt{E_D} - \sqrt{E_D+E}}{E^2}, & \text{for } E > E_D \end{cases}$$

where $\varepsilon_1(\omega)$ is the real part of the dielectric function;

$\varepsilon_1(\infty)$ is the value of $\varepsilon_1(\omega)$ at infinite angular

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frequency; and

wherein $\varepsilon_1(\infty)$ is a fitted parameter obtained from measured data of an optical property of the film.

9.   The method according to claim 8, including using the values for $\varepsilon_1(\omega)$ and $\varepsilon_2(\omega)$ obtained by the modeling to calculate the physical parameters refractive index n and extinction coefficient k of the film according to the relations:

$$n = \sqrt{\frac{1}{2}\left[\sqrt{\left(\frac{\varepsilon_1}{\varepsilon_2}\right)^2 + \left(\frac{\varepsilon_2}{\varepsilon_0}\right)^2} + \frac{\varepsilon_2}{\varepsilon_0}\right]}$$

$$k = \sqrt{\frac{1}{2}\left[\sqrt{\left(\frac{\varepsilon_1}{\varepsilon_0}\right)^2 + \left(\frac{\varepsilon_2}{\varepsilon_0}\right)^2} + \frac{\varepsilon_1}{\varepsilon_0}\right]}$$

10.   The method according to claim 7, wherein the measured data of an optical property of the film for obtaining the fitted parameters are from a reflectometer and/or an ellipsometer.

11.   The method according to claim 1, wherein the film is a semiconductor material containing at least one alien species as an impurity forming interband states in the semiconductor material.

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12.   The method according to claim 1, wherein the film is

selected from the group consisting of a semiconductor material and a

dielectric material.

13.   A method of material engineering for producing a film

having at least one desired optical property by a process which alters

interband states in the film to affect the property, comprising:

calibrating the magnitude of a process variable of the process to

produce a film against a fitted parameter of a modeling equation for

quantum mechanical transition between a band and interband states in a

band gap in the film, which fitted parameter is a function of the

magnitude of the process variable used to produce the processed film;

calculating the at least one optical property of a film for the

corresponding value of the fitted parameter; and

deciding the magnitude of the process variable to be used in the

process for producing a film having the desired at least one optical

property.

14.   The method according to claim 13, wherein the fitted

parameter is A in the equation:

$$\varepsilon_2(\omega) = \begin{cases} A\dfrac{\sqrt{E - E_D}}{E^2}, & \text{for } E > E_D \\ 0, & \text{for } E < E_D \end{cases}$$

where $\varepsilon_2(\omega)$ is the imaginary part of the dielectric function;

E is the incident photon energy;

E_D is the energy level of the interband state; and

wherein the values for A and E_D are fitted parameters obtained

from measured data of an optical property of the film.

15.   The method according to claim 13, wherein the process

variable is the rate of a gas flow containing an alien species used in the

process.

16.   The method according to claim 13, wherein the process

variable is selected from the group consisting of the temperature and the

time of processing the film.

17.   The method according to claim 13, further comprising

subjecting a film to the process which changes the concentration and/or

level of interband states in the film; and monitoring the magnitude of the

fitted parameter of the film produced by the process.

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18.   The method according to claim 13, wherein the film is a

semiconductor or dielectric material.

19.   In a process for producing a film having at least one desired

optical property, wherein the process introduces or controls interband

states in the film which affect the optical dispersion of the film, the

improvement comprising:

calibrating the magnitude of a process variable used in the process

to produce a film against a fitted parameter of a modeling equation for

quantum mechanics transition between a band and interband states in a

band gap in the film, which fitted parameter is a function of the

magnitude of the process variable used to produce the film; and

monitoring the magnitude of the fitted parameter of the film

produced by the process.

20.   The process according to claim 19, wherein the fitted

parameter is A in the equation:

$$\varepsilon_2(\omega) = \begin{cases} A\dfrac{\sqrt{E - E_D}}{E^2}, & \text{for } E > E_D \\ 0, & \text{for } E < E_D \end{cases}$$

where $\varepsilon_2(\omega)$ is the imaginary part of the dielectric

function;

E is the incident photon energy;

E_D is the energy level of the interband state; and

wherein A and E_D are fitted parameters obtained from measured

data of an optical property of the film.

21.   The process according to claim 19, further comprising

estimating the magnitude of the process variable used in the process from

the monitored fitted parameter and the calibrating.

22.   An apparatus for producing a film having at least one desired

physical parameter, comprising:

a processing device for introducing or controlling interband states

in a film which affect a physical parameter of the film;

an optical instrument for measuring a film which has been

processed by the processing device, the optical instrument producing

measured data as a result of the film measuring; and

a controller for adjusting the magnitude of a process variable of the

processing by the processing device, the controller receiving the

measured data from the optical instrument and having means for

calculating the physical parameter of the measured film using the measured data and a theoretical model relating the physical parameter to scattering caused by interband states in the film.

23.   The apparatus according to claim 22, wherein the means for calculating is a programmed computer.

24.   An apparatus comprising:

an optical instrument for measuring an optical property of a film containing interband states and producing measured data as a result of the film measuring; and

a programmed computer for calculating at least one physical parameter of the measured film using the measured data and a theoretical model relating the physical parameter to scattering caused by interband states.

25.   The apparatus according to claim 24, wherein the optical instrument is selected from the group consisting of a reflectometer and an ellipsometer.